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I N T E R I M R E P O R T

January - May 1963

of the French Mission for the prospection of Bauxite
in the Lower Mekong Basin

prepared by Mr. H. CRUYS Dr. Sc.
B.R.G.M. Geological Expert, Chief of the Mission

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INTERIM REPORT

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I.- INTRODUCTION.

This report describes the work achieved since the beginning of the year.

It may be recalled that the French Bauxite Mission resumed in November 1962 its activities in connexion with the Mekong. Our note of 5 January 1963, submitted to the 19th session of the Mekong Committee in VIENTIANE, was a brief account of the launching of our programme for CAMBODIA, LAOS and VIET-NAM.

We wish to thank all the officials who helped us in our work and contributed to the implementation of our programmes.

It is our pleasant duty to report the help our Mission received, in various fields, from the Mission Française d'Aide Economique et Technique (M.F.A.E.T.) in PHNOM-PENH and in SAIGON; the United Nations Technical Assistance Board in Phnom-Penh, as well as from the Cambodian, Laotian and Vietnamese government services, and particularly the Service des Mines, de l'Industrie et de l'Artisanat of CAMBODIA; the National Services of the Mines of LAOS and VIET-NAM, the Geographical Service of F.A.R.K. in PHNOM-PENH; the National Geographic Department of LAOS; the Geological Department of the University of Saigon, the Commissariat au Plan of Laos, the Préfecture and the Subdivision of Public Works in LUANG-PRABANG.

So as to be able to better evaluate the possibility of bauxite deposits, we studied the relevant geological and pedological material; we also studied promising geological sites from a geomorphological, structural and topographical viewpoint through aerial and topographical mapping.

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At the Service Géographique in PHNOM-PENH we made a stereoscopic examination of a considerable part of the aerial mapping of the Western part of Cambodia.

We stayed in Saigon from 5 to 20 February in order to complete at the Service des Mines and at the Faculty of Science the geological and pedological material we had begun to collect in Phnom-Penh at the Service des Mines, about Cambodia, Laos and Viet-Nam.

From 18 March to 2 April we visited Vientiane where we, inter alia, studied at the Service Géographique the aerial mapping of a number of promising regions of Laos.

Field checking surveys were carried out in the western part of Cambodia, in the Kirirom, Cardamomes, Kampot, Bat ambang and Sisophon regions.

A second visit made to Laos from April 21 to 5 May unfortunately was of no avail; owing to current politico-military developments we finally had to abandon an interesting prospecting programme in promising karstic ranges of ouralo-permian limestone in the Luang-Prabang region.

II.- DOCUMENTS.

The interest of a methodical study of data already available within the frame of geological and mining surveys need not be stressed again.

For our guidance and the better implementation of our mandate, we so far chiefly consulted the following publications:

- Many geological and pedological publications, most of which issued in the Bulletins du Service Géologique de l'Indochine.
- Geological map of Indochina at the scale of 1/2.000.000 (J. Fromaget et E. Saurin, Services Géologiques de l'Indochine, 1952).
- Geological map, Vietnam - Cambodia - Laos, 1/500.000 (Service Géographique national du Vietnam, 1961-1962), sections Luang-Prabang West (No. 4 W), Luang-Prabang East (No. 4 E), Vientiane (No. 7), Hué West (No. 11 W), Hué East (No. 11 E), Tourane (No. 12), Bangkok (No. 13), Khong West (No. 14 W), Khong East (No. 14 E), Qui Nhon (No. 15), Pak Nam (No. 16), Saigon West (No. 17 W), Saigon East (No. 17 E) and Nha Trang (No. 18).

/Geological...

- Geological map of Cambodia (4 sections) scale 1/400.000 (Société Shell of Cambodia, 1961)
- Topographical map of Indochina and Thailand, scale 1/250.000, (US Army Map Service, Washington, 1954-1958), sections Battambang (ND 48-9), Chantaburi (ND 48-13), Pursat (ND 48-14), Kas Kong (NC 48-1), Phnom-Penh (NC 48-2), Kampot (NC 48-5), Long Xuyen (NC 48-6), Vieng Pou Kha (NF 47-16), Moung Ngoi (NF 48-13), Moung Pak Beng (NE 47-4), Luang-Prabang (NE 48-1), Moung Nan (NE 47-8), Van Vieng (NE 48-5), Muang Loei (NE 47-12), Vientiane (NE 48-9), Kam Keut (NE 48-6), Vinh (NE 48-7), Thakhek (NE 48-10), Badon (NE 48-11), Saravane (ND 48-3), Ben Giang (ND 48-4), Khong (ND 48-7) and Muong May (ND 48-8).
- Photographical mapping (Cambodia), scale 1/40.000, of the regions of Sisophon, Battambang, Pailin, Tumpor, Pursat and Kampot, as well as of the south-western part of Cambodia covered by the Cardomomes and Kirirom ranges. Some 900 photographs from aerial surveys No. 27, 33, 42, 87, 88, 89, 94, 95, 96, 127, 128, 132, 134, 135, 136, 144, 146, 154, 157, 161, 162 and 164.
- Photographic mapping (Laos), scale 1/40.000, of the regions of Luang-Prabang - Vang Vieng and Paksane - Kam Keut - Thakhek, and the Bolovan highlands.
  Some 1,700 photographs from aerial surveys Nos. 29, 50, 54, 55, 65, 66, 100, 116, 118, 120, 121, 124, 155, 156, 158, 159, 160, 175, 176, 179, 181, 183, 184, 185, 188, 189, 190, 191, 192 and 193.

III.- GEOLOGY.

Our surveys naturally addressed themselves to geological formations in which bauxite might have developed, such as ancient sedimentary carbonated rock and some alumino-silicated rocks of the eruptive and metamorphic type, of various ages and petrographic nature.

What emerges from these studies are the following basic facts and data:

1) - In the lowlands, with their quarternary alluvial deposits, one mostly finds broken lateritic formations: Lateritic gravel or fine gravel, localized concretions and crusts with a compact pisolithic and vesicular or slaggy texture. But these formations always show a high iron contents; they even contain

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a high silico-clayish percentage and show no traces of bauxite. They furthermore usually do not belong to the truly residual type: they mostly are ferruginous alluvions or late pedological products of absolute accumulation of iron oxides through diagonal washing and lateral drift.

2) - The true (residual) laterites, of recent formation, also seem unfrequent in mountain areas, and even in crystalline ranges. It may be that geomorphologic aspects and climate conditions are not favorable.

3) - Contrary to the indications of the geological map of Cambodia at the scale of 1/400.000, our observations during our survey of the Cardamomes range led us to think that the high tablelands (altitudes : 300 to 500 meters) of these extensive sandstone formations (Indosinias) may not be covered by quarternary or tertiary basaltic formations. Laterite shields seem to be absent and we found no trace of bauxite.

Late basaltic formations appear in some valleys that cut into the Cardamomes range, but the clayish soils resulting from their decomposition, varying from reddish to brown-red in colour, showed no sign of lateritization proper.

4) - Effusive rocks, whether ancient or quarternary, especially rhyolites, dacites, andesites and basalts, occur very frequently in Cambodia, Laos and South Viet-Nam, where they often constitute extensive formations.

From a petrographic viewpoint, such lavic, alumino-silicated structures might deserve attention as regards the possibility of bauxite in their clayish or kaolinic formations resulting from chemical and pedogenetic alterations. However, no clearly bauxitic indication has been found yet. Pedological and geological texts seldom refer to alteration processes of tertiary and quaternary basalts or ancient volcanic rocks (rhyolite, dacite, andesite) having actually been carried to the point of complete lateritization.

Pagodite, of which layers are to be found in the great rhyolitic and dacitic ranges of western and northern Cambodia and south Laos, is a hard kaoline, basically made of a hydrated aluminium silicate, in this case kaolinite, resulting from deep alteration of rhyolites or dacites. This does not seem to contain aluminium.

Extensive basaltic outflows have recovered the sandstone and mesozoic crystalline basis. They gave, through decomposition under tropical conditions,

/extensive...

extensive pedological coatings of red, grey or black colour, clayish in texture and fertile as agronomers well know. Numerous analyses of soils resulting from basaltic decomposition, published in pedological studies, show that in the case of pratically all the samples coming from the different basaltic highlands of Viet-Nam, south Laos and eastern Cambodia, the silica percentage are about 40% and alumina percentages about 30%, indicating basically clayish or kaolinic alteration which therefore cannot be of the lateritic kind. Only certain samples, closely grouped, coming from the Boloven Highlands in south Laos, gave clearly different percentages: 35 to 46% Al203, for 13 to 15% Si02 only. Their interesting alumina-silica contents ratio is higher than for theoretical kaolinite, and therefore indicative of a comparatively high percentage of free alumina; this may denote an initial bauxitization phase.

5) - Among the most interesting geological aspects of Laos are the extensive fossil-bearing ouralo-permian limestone outcrops which, belonging to the anthracolitic substratum, emerge from the mesozoic Indosinias cover in stratigraphic "button-holes", or erosion windows.

It is mainly in the areas of Luang-Prabang, Vang-Vieng, Xieng Khouang, Kam Keut and Thakhet that such limestone formations are extensively represented, by great tabular or anticlinal and synclinal structures. Their karstic nature makes them easy to detect on aerial photographs.

From a geological viewpoint, it is interesting to note that in the vicinity of Luang-Prabang the high karstic formations are accompanied by extensive andesitic, permian and triasic appearances. The main limestone ranges in that region cover areas extending from 50 to some 400 Km^2. On their broad tabular sections, rising to an average height of about 1,500 meters, typical karst with innumerable and evenly distributed sink-holes, has developed. We then may assume that the karstic limestone highlands of Luang-Prabang may contain fossil, permian or triasic bauxite. What leads us to this belief is the analogy existing both from a lithologic and a geomorphologic viewpoint between the anthracolitic and triasic structures of the Luang-Prabang region and those actually recognized as bauxite-bearing in north Viet-Nam (regions of Lang Son, Dong Dang, Cao Bang, Bac Son, Quang Yen, etc...)

Tonkin bauxites are connected with karstic limestone outcrops, also ouralo-permian, and very extensive. These are accompanied by effusions of triasic rhyolites. The bauxites were constituted during emersion, that is continental,

/periods...

periods, occurring between the Permian and the Trias. Judging from the data of regional stratigraphy, their constitution can be set between middle Permian and middle Trias.

Now, the lower Trias of the region of Luang-Prabang must also have corresponded to a continental period. And the andesites of that region could have given, through alterations, an excellent alumina basis for the formation of bauxites in the karst (permian or triasic) of the neighbouring limestone areas.

It may be added that an indication of bauxitization of upper permian age was also found in Cambodia, in the limestone area of Battambang and Sisophon (see below).

6) - For us, it is now clear that:

a) The sandstone formation "Série de Khorat" in Thailand must be the equivalent of the sub-continental series "Indosinias" to which the mesozoic shales and sandstone of Laos and Cambodia belong.

b) The volcanic formations (rhyolites, andesites, tuff, etc...) which we observed last year in the regions of Lopburi and Petchabun in Thailand, and which are considered as of tertiary origin by highland geologists must be the equivalent of the extensive rhyolitic, andesitic, anthracolitic and triasic appearances found in Laos, Cambodia and Tonkin.

7) - Mr. E. SAURIN, geology professor at Saigon University, one of the chief contributors to the geological map of former Indochina, recently pointed to the existence of an indication of bauxite in some Permian sandstone heights near Sisophon and Battambang (western Cambodia).

He submitted in January 1963 to the Société Géologique de France a note containing the following observations:

- There is a bauxitic level in the area in Yabeina-Lepidolina of the Upper Permian of western Cambodia. Near Sisophon, J. Gubler (1935) reported the presence of a "red diorite-sand" bed between sandstone layers at Productus of the base of the Phnom Khla Kaun, also known as Phnom Krol.

/This red...

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This red layer is 1,5 m thick; it has the appearance of a fine grain, compact, brown-red clay with black patches; it actually is a clay bauxite with 56% alumina if red, and 45% if black, basically constituted by an alumino-ferric compound with ferric granulations of a darker colour. The contact of that layer with the Fusuline. and Brachyopod-bearing limestone formation surrounding it, is clear-cut, straight and close, both for the walls and the ceiling; there is no sign of emersion.... This layer extends towards the East into the near-by hill of Phnom Tup where its grain is finer...

- At 80 Km south of Sisophon, in the vicinity of Battambang, this bauxitic level can also be observed in the Phnoms Kdong, Sampou and Trung Mean; where its lay-out and bauxitic elements are more complex than at the Krol and Tup.....

At the bottom of the Kdong, those vertical layers include breccias of zoogenous limestone whose elements are impregnated and surrounded by alumino-ferruginous streaks; stone-bauxites, grey-green with red spots, containing 62% alumina; then hematite-like bauxites, very hard, red-brown, whose microscopic texture, as in the case of the former is of a colloidal and pisolitic nature. Freed and dislocated by erosion, they constitute on a short stretch near the small pass conglomerations of ferruginous scales in the Sampou, the bauxitic level can be seen near the summit on the eastern slope and half way down the western slope, where it is chiefly represented, between breccia limestone elements, by bauxitic breaks with bauxite elements cemented together by alumino-ferruginous limestone; their alumina contents varies with the density of those elements; but one also finds evidence of hematite-like bauxite, as well as clay bauxite, the latter similar to that found at the Krol...

At little Phnom Trung Mean, at 1,5 Km west of the Sampou, one finds again on the western side,at the foot of the hill, on the theoretical prolongation of the Kdong-Sampou depression, hematitic bauxite in scales and conglomerations, and, in the overhanging limestone formations, bauxitic breccias.

/The origin...

The origin of this bauxitic level, appearing between organogenous marine sandstones of Upper Permian, can be explained as follows: the Permian sea was bordered by emerged lands, in particular the crystalline dome of Pailin (gneiss, amphibolites, etc...); their alteration during the Upper Permian age resulted in detritic matter and ferro-aluminous solutions being sedimented in the neighbouring sea.

Our survey in Battambang and Sisophon regions brought nothing new or more interesting than Mr. SAURIN's observations and conclusions. In this area, as in the region of Kampot, there only remain a few groups of fossil-bearing, ouralo-permian limestone elevations of mediocre size, generally reduced by erosion to mere isolated "Phnoms" separated from one another by more or less extensive alluvial quarternary lowlands.

These residual limestone elevations do not contain "terra rossa" but only blackish and brownish "rendzina". In the karst - limestone rocks showing numerous cracks and crevices - bauxitic formations are absent.

In view of such geological conditions, and especially of the lack of extensiveness and volume of this bauxitic level, the uneven character of its bauxite contents and its unusual configuration, its often very ferruginous nature and its high lime contents, we do not think that this ancient bauxite can be of any practical interest.

It nevertheless indicates that climatic conditions during the Permian age must have been favorable to the development of bauxitic laterites from silico-aluminous rocks.

IV.- CONCLUSIONS.

Briefly summed up, our conclusions are as follows:

In the course of our surveys in Cambodia, Laos, and Viet-Nam, no really promising indication has been found. The results of the prospecting activities conducted by us in the Lower Mekong Basin for bauxite of fossil or recent origins are therefore negative.

The signs of Permian bauxitization, as detected by Mr. SAURIN in the limestone area of Sisophon and Battambang (western Cambodia) are most interesting from a theoretical viewpoint, but the bauxitic level does not seem to be of economic interest.

/The aluminous...

The aluminous soils resulting of the decomposition of the basaltic highlands in Cambodia, Laos and Viet-Nam, examined by French pedologists, have not (yet?) reached the stage of bauxito-laterization proper.

In short, one still does not know in the Basin of indications of industrially significant bauxite deposits.

However, our geological and photogeomorphological surveys warrant some hope as regards bauxite possibilities in the karstic ouralo-permian ranges of Laos.

Whatever the origin of the bauxites existing in limestone ranges - be it of autochtonous origin (colluvial and eluvial transformation, by sub-aerial alteration of limestone beds, through an intermediate stage of clays resulting from decalcification of "terra rossa") or of allochtonous origin (introduction by winds of water of ferro-aluminous and bauxitic matter in karstic zones) - we assume that some of the great limestone ranges in Laos, and in particular the karstic highlands of Luang-Prabang, could be favourable to the existence of fossil bauxite, or permian or triasic origin.

A bauxite deposit, if found in the Luang-Prabang area, could be directly utilized for the industrialization of the Lower Mekong Basin. But normal politico-military conditions will have to prevail before serious prospection work can be undertaken in that area under perfect security conditions.

V.- PROGRAMME.

The Bauxite Mission will terminate its activities in the course of the present year.

We still have on our programme a small-scale survey in the basaltic ranges of eastern Cambodia and south Laos (Hauts Chlong and Bolovens). Those field activities will of course have to be concluded before the height of the rainy season, thereforebefore the end of July.

A detailed final report will be prepared and submitted to the Mekong Committee, giving an overall description of the activities conducted in the four riparian countries and of the results that have been achieved.

PHNOM-PENH, 15 May 1963

(Signed) H. CRUYS